UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE

Report On Progress---

In The Development And Improvement Of Estimating Methods

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In The Agricultural Statistics Division

(For Administrative Use Only)

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PREFACE

I have long felt the need of a closer tie between the workers who give their entire time to statistical analysis directed to our field of work and those of us who turn out the grist of almost daily statistical reports of current service character in the 41 field offices and here in Washington. I am gratified to note each successive symbol of advance in this respect, of which this progress report is one.

Analytical studies are of utmost importance to our program if we are to remain alive and alert to improvements that can be made in our current work methodologies. The attitude of definitely and constantly seeking this improvement has been an outstanding characteristic of our organization. Naturally, we will make most progress only if the workers in both fields -- the analysts and those "on the firing line" -- are closely attuned. Each should exercise patience and seek a sympathetic understanding of the other's primary task. Both should recognize the essentiality of the medium of statistical refinement and the necessity of addressing its effort primarily to the discovery of new, workable techniques adaptable to the Division's everyday reporting task -- its first order of business.

Our Statisticians are on a pressure assignment, invariably facing a deadline. It is recognized that there is little time to spare for "trial and error" exploration when one of a multitude of reports must be turned out. On the other hand, a new analytical procedure is by nature experimental, a matter of cutting and fitting new approaches to old problems, and its results are more slowly produced. In spite of the divergence of activity in the two fields, marked progress has been made in focusing attention of both types of workers on the Division's most pressing statistical problems and we are assured this will continue.

The progress reports are quite largely the outgrowth of expressed wishes of our State Statisticians for some means of keeping informed on the Division's analytical work and results. I hope these reports will help in arriving at a better understanding of our common goals, and I invite all to make worthwhile contributions to future issues.

W. F. Callander

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INTRODUCTION

During the past several years the statistical research activity of the Agricultural Statistics Division has increased rapidly. Statistical studies are being directed by members of the Division's technical staff at Ames, Iowa; Raleigh, North Carolina; Gulfport, Mississippi; New York City, New York; Des Moines, Iowa; and Little Rock, Arkansas.

In C.E.M. #849, June 19, 1941, Mr. W. F. Callander, Head Agricultural Statistician presented a general discussion of the Division's analytical program and established a permanent Research Committee now composed of Joseph A. Becker, Chairman, Glenn D. Simpson, Secretary, R. K. Smith, and Walter A. Hendricks.

One of the major functions of the Research Committee is that of acquainting the staff of the Division with the statistical analysis being conducted. It is hoped that by keeping the field men currently posted on progress that practical field problems will more readily find a prominent place in the analytical program and also that new and useful statistical tools will be more rapidly adapted to field office use.

It is pointed out that statistical analysis must be projected along two distinct lines. First is the evaluation and improvement of present estimating methods and second, the longer range program of discovery, application, and evaluation of new or alternative methods of estimation.

This progress report presents a brief description of 8 separate studies that have been or are being conducted by Division statisticians. Final and detailed reports will be published covering each study. The treatment herein is non-technical and for each study there is presented a brief introduction, the objectives of the study, brief statement of procedure, significant conclusions or observations to date and the names of the statisticians conducting the work. Although brief, this presentation is designed to permit each field man to gain a general speaking knowledge of the Division's various statistical studies.

The Research Committee has considerable detailed technical and operational information concerning each of the studies and field men are invited to avail themselves of it either for informational purposes or for use in organizing studies along similar lines.

The original detailed unpublished manuscripts and progress reports upon which this publication is based were prepared by the various study leaders. Mr. E. Arthur Koop, Junior Agricultural Statistician at Ames, Iowa translated much of the technical data into narrative form. The Secretary of the Research Committee further edited and briefed the reports so as to permit a reading in minimum time yet attempting to retain most of the highlights of each study.

This publication is for Divisional use and may be used by field statisticians as a means of presenting their statistical studies for the information of other field offices.

The next progress report will contain a corresponding presentation for a group of studies that have been or are being processed on the New York City, W.P.A. Project. The second issue will also contain statements of progress and additional conclusions concerning the studies herein presented. Progress will be reported thereafter when new significant conclusions are obtained or when new methods of analysis are undertaken.

The comments and criticisms of the field men concerning this publication or concerning any of the studies are invited.

Joseph A Becker

Joseph A. Becker,
Chairman Research Committee

(The information in this report was assembled and edited by Glenn D. Simpson, Secretary, Division Research Committee).

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PRE-HARVEST WHEAT SURVEY

The Pre-Harvest Wheat Survey was a detailed investigation into the problems of pre-harvest wheat route sampling and was one of the first studies to be conducted by the Agricultural Statistics Division through its cooperative arrangement with the Statistical Laboratory located at Iowa State College, Ames, Iowa.

The first pre-harvest survey of wheat (head samples) was taken in North Dakota in the summer of 1938. The survey was extended in 1939 to include the important wheat producing areas in the States of Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, and Minnesota. The 1940 survey was limited to Oklahoma and Kansas. Throughout the entire period statistical analysis of the survey data was carried on. The field sampling was not conducted in 1941; the project, however, has proved to be of sufficient value and utility to be incorporated with the regular Divisional activities, commencing in 1942.

The specific objectives of the survey were: (a) To develop a sampling technique that will provide at harvest and prior to marketing accurate estimates of the quality of the wheat (physical, chemical, and milling and baking) for small areas within a State; (b) to furnish a sampling technique that will at harvest and prior to marketing provide basis for estimates of acreage and production by varieties; (c) to provide an objective method of sampling the wheat crop in order to make timely estimates of yield per acre which could serve as an independent check on yield data now being obtained from voluntary reports; (d) to test further the use of the crop meter as a basis for estimating the wheat acreage at harvest, which would serve as an independent check on estimates that are based upon data obtained from voluntary reports; (e) to determine what plant characteristics most closely associated with yield may be measured during the growing season and can be used as a basis for objectively forecasting yield prior to harvest.

The surveys were based on a sample of heads taken from fields just prior to the harvest (about 5 days). The samples were obtained by crews of two men in a car, one crew in 1938, three in 1939 and four in 1940. The 1938 survey started in southeastern North Dakota and the samplers moved northward sampling the crop as it ripened. In 1939 and 1940 the samplers started in southwestern Oklahoma and moved northward. In all years, the cars were equipped with crop meters used for measuring the frontage and also for determining the distribution of fields to be sampled in proportion to the measured frontage of wheat. This was accomplished by holding the number of miles traveled, while the crop meter was in operation, proportional to the land area and taking a sample at intervals of two miles of wheat frontage as indicated by the crop meter. By following this procedure, the sample was stratified by counties, thereby eliminating the between county variability and increasing accuracy accordingly. Two samples, each from 1/5000 of an acre, were taken in each field sampled. Sample units were selected purely at random thus eliminating any personal judgment or bias in their selection. Random numbers were used both for choosing the point of entry and the distance in the fields where the samples were taken. All the heads within the units were cut and placed in envelopes and mailed each night to a central laboratory where counts, measurements, and chemical determinations were made.

Some of the more important conclusions resulting from an analysis of the data are as follows:

1. After detailed statistical investigations of the Pre-Harvest Wheat Survey data, it appears that the route sampling of a crop of wheat at or prior to harvest furnishes a useful method for estimating quality and production.

2. As a supplement to present methods of estimating wheat production, the Pre-Harvest Wheat Survey might be expected to promote timeliness, geographic detail, and objectivity in estimating both production and quality of the crop at harvest.

3. The survey method of route sampling will probably be most useful in unusual years when abnormal development of the wheat crop creates production conditions not readily detected by usual crop reporting methods.

4. Relatively small sampling errors were found in the estimates of protein and test weight as compared with the sampling errors found in the yield and acreage estimates.

5. Slight bias is believed to occur in the estimates of protein and test weight because some fields were sampled prior to harvest when the wheat kernel might not yet have indicated its quality as actually shown at harvest.

6. The estimates of yield and acreage were found to contain systematic errors of bias as well as random sampling errors.

7. Analysis of the data indicates that the random component of error can be reduced sufficiently through improved sampling technique to render this source of error relatively unimportant in the estimates for both quality and production.

8. The systematic error or bias in the yield and acreage estimates presents a more serious problem in that the total amount of bias differs between years and between States in a given year.

9. In order to obtain more accurate estimates from the survey, it will be necessary to investigate further the sources of bias found and to establish a more definite basis for removing this component of error from the final estimates.

10. In order to obtain a maximum amount of information per dollar spent in estimating production, the cost analysis indicates that the sampling interval should have been increased and the total mileage driven should have been increased in each district.

The pre-harvest surveys were directed by A. J. King, who also was in charge of field sampling in 1939 while J. E. Pallesen was in charge of the laboratory in that year. Archie Langley and George D. Harrell each had charge of a sampling crew throughout the 1939 survey. In 1940 Miles McPeek was in charge of field sampling and Floyd E. Davis in charge of the laboratory. K. E. Logan and E. O. Schlotzhauer each was in charge of a sampling crew during a part of the 1940 survey, with Floyd E. Johnson also in charge of one of the crews. Dale E. McCarty assisted in the summarization of the data, preparation of the current reports, and statistical analysis. Mary Lou Bucher also assisted in the statistical analysis. Catherine J. Senf supervised the work carried on in New York City under the Work Projects Administration.

Varieties were identified by J. W. Kirkbride, Kenneth B. Porter, and J. F. Fisher under the supervision of L. P. Reitz and Ted Stoa of the Kansas and North Dakota Experiment Stations. H. H. Laude offered valuable assistance toward the operation of the laboratory at Manhattan in 1940. The chemical determinations were made under the direction of C. O. Swanson and E. G. Bayfield of the Kansas Station and R. H. Harris of the North Dakota Station. Members of

the staff of the Statistical Laboratory who gave valuable assistance, criticism, and suggestions were G. W. Snedecor, W. G. Cochran, and E. E. Houseman. Joseph A. Becker and R. K. Smith of the Agricultural Marketing Service assisted in planning the survey.

The official report of the Pre-Harvest Wheat Survey, in which the field work and mathematical analysis are presented in detail, is now in process of printing. This report, to be known as Technical Bulletin 814, will be distributed to Divisional field offices and other interested persons as soon as it is off the press.

THE AAA-AMS ACREAGE SAMPLE SURVEY IN IOWA AND INDIANA

The section sample survey of crop acreage in Iowa and Indiana for the crops of 1940 and 1941, conducted jointly by the Agricultural Marketing Service and the Agricultural Adjustment Administration is the first large scale exploration of a new method of sampling based upon a rigid geographic sampling unit in the form of a square mile section of land. This investigation has been conducted cooperatively by utilizing the Agricultural Adjustment Administration's aerial photographs and its State and county personnel organization in collecting the sample data, and the facilities and personnel of the Agricultural Marketing Service for statistical analysis of the data and interpretation of results.

Ground was first broken in working out the theory of geographic acreage samples in the 19 county acreage study of 1938-39 made by a W.P.A. Research Project of New York City in cooperation with the Division. This 19 county study was based upon A.A.A. data and aerial photographs for 19 selected counties in the north central region of the United States. Part of the statistical findings of the 19 county study appears in a published paper entitled "New Developments in Agricultural Sampling", by A. J. King and Glenn D. Simpson. (Journal of Farm Economics, Volume XXII, No. 1, February 1940.)

Based upon the above mentioned information and experience the "Iowa-Indiana Section Sample Survey" was designed with a view to solving the following major objectives: (a) To obtain an acreage sample, by objective methods, using a constant sized sampling unit, the total population of which remains constant from year to year; (b) to determine the reliability of such a sample in making State and county estimates of crop acreage for any given year; (c) to determine the reliability of such a sample in measuring year to year changes in crop acreages by means of "matching" or "identical" samples; (d) to measure the effect of nonparticipating farms when A.A.A. participating farm data are used as a basis for estimating; and (e) to evaluate the estimating efficiency of this type sample in relation to its cost.

The sample in each State consists of single sections of land, selected at random, proportionate in number to the total number of sections in each township. Approximately 3,200 sections in Iowa and 2,000 sections in Indiana constitute the sample. Enlarged aerial photographs were obtained for the sample sections on which the section boundaries were drawn in ink. The enlargements were of sufficient size to permit drawing in the field boundaries and writing in the crop identification and measured area of the fields. A representative of the A.A.A. visited all the farms in each of the sample sections and identified on the photographs the crops grown or land utilization of each field within the section boundaries. The area of each field was obtained in the A.A.A. county office by planimetry. The farms within the sample sections were identified on the photographs as to their participation or nonparticipation in the A.A.A. program

by use of different colored pencils in entering the necessary information.

The aerial photographs, marked to show the crop identification and the measured area of the fields, were sent by the county to the State A.A.A. office for inspection for completeness and accuracy of the crop identification and measurements. After this check, the photographs were turned over to the offices of the State Agricultural Statisticians where the data were transferred to listing sheets and summarized under the supervision of the statistician. The statistical analysis of the data was conducted in the New York City W.P.A. project office under the supervision of J. H. Peters from the Washington office of the Agricultural Statistics Division.

Analysis of the data is not complete, since the 1941 crop year has just closed and the assembly of the sample data not yet finished. Analysis of the 1940 data reveals that, in general, an acreage sample of the kind and size obtained is quite dependable for making State estimates of the acreage of major crops for these two States. The State acreage of corn estimated from this sample is statistically accurate to within less than 1 percent for Iowa and within 2 percent for Indiana. The State estimates for oats, wheat, and soybeans in Iowa and oats and wheat in Indiana are within 2 to 3 percent of the Board's previously established acreages. For the less important crops, the acreage of which is less uniformly distributed it would be necessary either to have very much larger samples, or to be content with a wider range in the accuracy of the estimates. When it comes to use of this sample for making county estimates, the results follow much the same pattern. In the case of Iowa corn, the expanded acreages are within the limits of 5 percent accuracy in over half of the counties. The study will be carried through to classification of the crops for which such samples are adequate for county estimates, for district estimates, and for State estimates, respectively, and determination of the accuracy of the sample for estimation of the crop acreage in each case.

The analysis of the "matched" sample, of course, has not begun. Great hope is held for the results when using matched geographic samples in measuring year to year changes in crop acreages. These hopes are predicated upon the ability, when using this type sample, to control the biases that enter into the Division's regular matched samples.

Analysis of the cost factors will necessarily come at a later date. This objective is one of the most important since improved accuracy of estimation must be evaluated in conjunction with the costs involved in obtaining and analyzing new types of data.

This sampling project was planned by representatives of the Agricultural Statistics Division, Agricultural Marketing Service, and the North Central Division of the A.A.A. The work was supervised by J. H. Peters and Miles McPeek (1940) under the direction of R. K. Smith. The field operations were directed by M. L. Anderson, W. E. Blackware, and Ralph H. Moyer of the Washington office of the A.A.A., and by several members of the Iowa and Indiana State Committees. The A.M.S. field work of assembling the data was supervised by M. M. Justin and L. M. Carl. Statistical computations were made by a New York City W.P.A. Project under the direction of J. H. Peters and Catherine Senf The sample was designed and the analytical procedures were outlined at the Statistical Laboratory, Ames, Iowa, by George D. Harrell and Mary Lou Bucher under the direction of A. J. King.

THE FARM ENUMERATION SURVEYS OF ARKANSAS AND IOWA

In March 1940, the Agricultural Marketing Service inaugurated the Farm Enumeration Surveys in the States of Arkansas and Iowa. This research work was undertaken by means of facilities of the Works Projects Administration. The studies were designed essentially to test the sample census theory.

The general structure of these enumeration projects is based upon the monthly enumeration of a sample of farms in each county. Centering on the first of the month, the enumerator visits a pre-determined sample of farms once each month. During the middle of the month the enumerator obtains price data by visiting merchants in the towns and villages of his county. In each State there is a central tabulation unit which assembles the enumerated data for transmission to Washington in a manner much similar to that used by field offices in submitting their regular reports.

The projects were originally entitled "Farm Employment Survey", since the most important data obtained concered farm employment. As the projects developed they have been expanded to obtain data on acreage, livestock, farm management items, farm tenure, farm machinery, etc. Because of this expanded field of enumeration, the projects are now called "Farm Enumeration Survey".

Neither of the States is now using the original samples that were drawn. In the spring of 1941, the samples were re-drawn partly because of error in the first drawings and partly because of the desire to test different methods of stratification.

The first of the month enumeration is approximately 10 days in length whereas the 15th of the month period is of about 6 days' duration. The 10-day period is based upon the requirements that the enumerator spend 1 day in each sampling unit. Although this latter requirement was originally made necessary by W.P.A. regulations it has proved to be an efficient control and should be considered in the operation of any sample census procedure. In cases where the sampling unit does not contain sufficient farms to keep the enumerator busy the entire day, he is instructed systematically to enumerate data for farms immediately adjacent to the base section.

The specific objectives of the original undertaking were as follows: (a) To test sample census procedure; (b) to determine the accuracy of estimates made by "per farm", "per block (section)", and "ratio" methods of expansion; (c) to study the administrative problems involved in theoperation of a large sampling project employing a regular staff of field enumerators; (d) to determine the necessary costs in the successful operation of a sampling project of this kind; (e) to experiment with the enumeration of economic and social information comprising farm receipts, expenditures, inventories, incomes and other data relating to rural life; (f) to obtain reliable monthly estimates of farm employment; (g) to determine an average scale of prices paid and received by farmers.

An average of 10 square-mile sections per county, selected at random, constitute the sample. The enumerator visits each farmstead that falls <u>within</u> the boundaries of the sample section. It is highly significant to note a major difference between this type of controlled sample and the rigidly controlled section sample that is discussed elsewhere in this publication (Iowa-Indiana Section Sample Survey). In this latter undertaking any land that falls outside of the section boundaries is eliminated from the sample, leaving a sampling unit that is one square mile in area. In the Farm Enumeration Survey the section is

used as a means of locating the farmsteads that are to be enumerated each month. As can be seen, the land for these farmsteads may fall inside or outside the base section.

The two methods of stratification being used at the present time are 10 sections drawn at random from among all sections in each county (Arkansas) and the quarter county stratification in which each county is quartered and three sections drawn at random from each quarter (Iowa). The theory of this latter stratification is that if no significant difference is found in the variances of the four quarters it would be possible to drop one or two quarters from the sample and yet have results as accurate or nearly as accurate as results yielded by the entire sample.

Schedules are enumerated throughout the year as follows: Once each month the farm employment schedule is enumerated for every farm in the sample section. In June and November, an acreage schedule is enumerated which contains the same or nearly the same inquiries as those that appear on the June Acreage and Rural Carrier Cards. The acreage schedules are also enumerated during the first of the month enumeration period. Livestock questionnaires, corresponding to the Division's regular livestock inquiries, are enumerated at the same time that the Division's livestock surveys are undertaken. In addition to these regular inquiries the Division has sandwiched in special inquiries both for Divisional use and for other interested Governmental agencies. In nearly every first of the month enumeration period, the enumerator completes two questionnaires and in some months he completes three. The questionnaires are held to minimum length and observations are being made to determine the most efficient number of questions for use in a Nation-wide sample census.

Data obtained in the monthly enumerations are used for two purposes: (1) The indications obtained from the summaries are used as independent indications in conjunction with the Division's regular farm labor, price, livestock, and acreage surveys; (2) the data obtained are also basic to an intense research analysis that is carried on at a slower pace. The analytical work of the intense research program is conducted in the State project office, in the statistical laboratories at Ames, Iowa, and Raleigh, North Carolina, and at the office of the W.P.A. project in New York City.

At the present time only a comparatively few of the anticipated final results have been obtained. Some of the major objectives, however, have been obtained and significant conclusions reached concerning others. The Division has learned a great deal about the problems involved in the administration of this kind of sample census work. It is felt that as a result of these projects the Division could design and participate in a Nation-wide sample census of agriculture with a minimum of delay. The proposed Nation-wide survey designed to obtain statistics concerning farm labor is based fundamentally upon the Division's experience both administratively and statistically in the Arkansas and Iowa enumeration projects.

To date little has been done in the analysis of the acreage or livestock data. The superficial examination of the results, however, reveal that the data can be used to estimate State acreages with a reasonable degree of accuracy. Some detailed research has been conducted concerning farm labor in 36 of the Iowa counties. A series of farm employment statistics have been established. The two methods that have been used to expand the sample data to a State estimate are the per-farm and per-section expansions.

Other significant conclusions obtained to date are that the enumerator's error is probably of greater significance than any other kind of error entering the data. This confirms the belief that in any future enumerative sample procedure the employment of competent enumerators, together with competent instruction and direction, are of utmost importance. One of the major sources of enumerator's

.or is the tendency to over-enumerate. This is reflected in the practice of the enumerators to include farms as part of the base section when such farms do not properly belong there. Another source of enumerator's error is the occasional tendency for the enumerator, in spite of all checks and controls, to get outside of the base section in his enumeration. This is especially true where section boundaries are not clearly defined. The effect of this type of error diminishes as the enumerator gains experience and knowledge of his territory.

It has been reasonably proved that the type of controlled sample employed in these two States is adaptable with certain regional modifications to Nation-wide sample census procedure. It has also been shown that a field survey can be enumerated and summarized in a very short period of time (two weeks). Observation to date indicates that it costs approximately 52 cents per schedule to get current results before the Crop Reporting Board.

The analysis of the data is constantly going on and it is anticipated that more rather than fewer results will be obtained in the next few months. The surveys are approved for operation until June 1942.

Many members of the Division have participated very actively in the operation of these two State projects. The original project was designed and set up by Dr. Charles F. Sarle, now with the Weather Bureau, and Roger Hale. The projects are supervised by the State Agricultural Statisticians, Stewart L. Bryan and L. M. Carl. The statistical laboratory at Ames, Iowa, under the direction of A. J. King has the responsibility of the technical design and direction of the Iowa project. The laboratory at Raleigh, North Carolina, under the direction of W. A. Hendricks, has a similar function for the Arkansas project. Each State project is supervised directly by a Project Supervisor who is a W.P.A. employee selected by the Division. The Project Supervisors are A. C. London, Arkansas and O. Mosher in Iowa, who recently succeeded Joe Dodson who resigned. The Division Research Committee has the policy-making responsibility for the projects. Coordination of the research and administrative functions of the two projects is centered in the office of the Secretary of the Research Committee. Each project has a technician who is paid by W.P.A., but selected by the Division and meets Division requirements for Junior Agricultural Statistician. The Arkansas technician job is vacant at the present time and Dale McCarty, a Division trained man, is functioning on the Iowa project. Other members of the Division who have given a great deal of time to the projects are George Harrell in Arkansas; Floyd E. Davis, Iowa; Paul L. Koenig, R. K. Smith, Joseph A. Becker, and Roger Hale.

SPECIAL TOBACCO SURVEY AND ANALYSIS

In the fall of 1934 it was decided that due to the importance of tobacco and the difficulty of estimating production from the regular surveys, special surveys designed to obtain data on tobacco only should be inaugurated. Accordingly, in the early spring of 1935 special tobacco inquiries were mailed from Washington to farmers in all the tobacco States to obtain data on the 1934 and 1933 tobacco crops. About the same time the next spring a similar survey was made to obtain data on the 1935 and 1934 crops. The results clearly showed the value of these surveys and it was therefore decided to make them a regular part of our program and to transfer the work of mailing, tabulating, and summarizing the inquiries to the field offices. It was also decided to conduct special tobacco surveys in June and October as well as in the spring. The result is that there are now available a comparable series of data from the June and October surveys for the period 1936 to date, and since 1934 for the March survey. The 1935 and 1934 data, however, are not entirely comparable with that obtained since that time as the number of schedules tabulated was materially greater and the questions on the schedules were not exactly the same.

The series has now been established long enough to make it possible to evaluate the data and to determine some of the weaknesses of the surveys and to consider possible means of correcting them. With that object in view the Agricultural Statistics Division, by use of facilities available in connection with the New York City W.P.A. project, undertook a research program designed to make a careful re-analysis of the special tobacco survey data for Kentucky and such other States as seemed necessary and desirable. Kentucky was selected for this study primarily because it produces about 70 percent of the Burley tobacco crop which is not only the most important single type of tobacco grown in this country, but is the one which at present we are having the greatest difficulty in estimating. Another consideration was that in addition to Burley, Kentucky produces five other types of tobacco, of which three are classed as dark fired (types 22, 23, 24) and two belong to the dark air-cured class (types 35, 36).

Analysis of the data has not been completed as yet but some deductions, if not conclusions, can be made from the results so far attained. For example, it has been found that the standard error of the sample yield of Burley tobacco is about 40 pounds. This would indicate that the Burley tobacco yield sample is sufficiently large to assume stability and that no increase in number of schedules tabulated is necessary. It was assumed that the optimum distribution of schedules would be that based on acreage of Burley tobacco in each area and the variability of area yields. The standard error of the sample yield received from the optimum distribution was about 33 pounds compared with about 40 pounds from the actual sample. It would appear, therefore, that re-distribution of the sample would not result in a statistically significant improvement in the yield indications.

The matching of year to year identical reports has never been a regular part of the analysis of the special tobacco survey data as it was believed that the results would not justify the additional labor required. The value of all identical yield indication has been a matter of considerable discussion, however, and it was therefore decided to obtain an identical sample during the analysis in New York. The Burley tobacco yields from the identical sample were so little different from those of the entire sample as to be of no significant value. The average indications from the identical samples have not been studied as yet, but so far as yields per acre are concerned the labor involved in preparing an identical sample from the special tobacco surveys cannot be justified.

It has been well understood that there is a considerable discrepancy between yields submitted by growers in the fall, before their tobacco has been marketed, and the yields they report the following spring, after the crop has been sold and actual yields are known. This bias or error is a combination of cash crop bias and the inability of growers accurately to estimate their yields before the tobacco has been weighed for selling. The extent of this bias and its constancy from year to year had never been measured and an attempt to do so was therefore made by matching reports from the October survey with reports from the following March survey. The results were that in the fall of 1937 and 1939 (rather comparable crop years) tobacco reporters understated the yields for their own farms by 8 and 9 percent, respectively; in October 1936 (a drought year) they understated their yields nearly 13 percent and in 1938 they overstated their yields about 5 percent. The crop in 1938 grew rather well and appeared to cure satisfactorily but when put on the scales it weighed very light. Looking at the above figures rather casually it appears that normally growers understate their yields around 8 or 9 percent but that in years of unusual conditions the error is much greater. This means that in evaluating chart yield indications a great deal of attention must be given to comparable crop years.

To sum up, the analysis to date seems to indicate that the sample obtained is large enough and that it does not particularly need to be re-stratified, but that much study must be given to bias in yield indications as growers themselves cannot or at least do not report in the fall accurate estimates of their tobacco crops. In estimating yields it is evident that the statistician still must know and properly evaluate a great deal more than is shown on a dot chart.

The study was designed and supervised by E. M. Brooks. The work was conducted as part of the New York City W.P.A. project under the supervision of E. M. Brooks and Catherine Senf.

CORN EAR MEASUREMENTS AND WEIGHTS
(CORN ROUTE SURVEYS)

Systematic ear measurements and field observations of corn were inaugurated by the Crop Reporting Board in 1933. Succeeding surveys indicated that accurate estimates of yield could be formed from a relatively few plant observations gathered prior to harvest.

Washington Route Survey: In 1933, J. L. Orr and L. H. Wiland made a reconnaissance survey of the Corn Belt for the purpose of laying out a route that would traverse the main corn areas and at the same time require a minimum expenditure of time and money to cover. The route selected covers about 4,800 miles and crosses the areas of heaviest corn acreage concentration in Ohio, Indiana, Illinois, Iowa, Missouri, Kansas, Nebraska, South Dakota, and Minnesota. In initiating these trips the Crop Reporting Board had in mind the development of an objective system of estimating yield per acre from specific yield attributes which could be measured.

A stop is made every 10 miles of road frontage. In 1939 three counts were made at each stop. Each count consisted of two 5-hill sections of adjoining rows in the case of checked corn or two 15-foot sections if the field was drilled. Observation made at the first count included method of planting, width of row, height and diameter of stalks in sample, number of plants, type, stage of maturity, number of ears, and length and diameter of each of the first 10 ears. Each of the first 10 ears was also examined for percent fill, presence of ear worm, dry rot, smut and chaffiness. The second count covered only the number of ears, the third the number of plants and ears. General field observations covered extent of weediness, presence of grasshopper, chinch bug and soil damage, and percent of lodging.

So far, the Board has concerned itself mainly with collecting the raw data and improving the technique of the measurements. Some work, however, has been done on the conversion of the material to yield per acre data and this has brought forth many problems on sampling and methods of resolving objective measurements into yield per acre.

Iowa Route Survey: The Iowa field office began making ear counts in 1930. In that year the Iowa statistician and a member of the Agronomy Department from Iowa State College, made field counts over a distance of 1,315 miles through representative portions of Iowa. In 1932 the Iowa statisticians developed and put into practice a system of making random counts of number of ears on 10-hill samples, estimating the weight in ounces of shelled corn of the samples and converting these to yields per acre. Stops were made at 5-mile intervals and two counts were made at each stop. The estimates of weight of ears in the samples were made by sight inspection and hefting the ears individually. Frequent stops were made to compare the estimates of weights made in the field with the actual weight secured on tested scales. The average yield calculated from ear weight estimates was 45.2 bushels per acre as compared with 43.8 bushels shown by the

crop reporters. This close agreement served both to confirm the reporters' average and to give credence to the method of estimating yields by representative sample ear weight tests.

Indiana Route Survey: Ear counts have been made for several years by representatives of the Indiana field office. In 1939 two counts on an area of 1/70 acre each were made at 20-mile intervals over a route which extended through 89 of the 92 Indiana counties. In the method used by the Indiana statisticians the ears were not measured but instead were rated for size by comparison with a standard ear (1/100 bushel) which had a rating of 1.0. Individual ear ratings were then resolved into total number of standard ears for the sample. In making the counts ample discount was made for moisture so that the indicated yield would be on a dry basis. Later in the season ears on eight samples were counted and rated in the usual way and then husked and weighed after which the percentage of moisture in the grain was determined. The indicated average yield per acre of these samples based on the standard ear method was 54.4 bushels. The computed yield on the basis of 16 percent moisture was 57.4 bushels. Since it was suspected that the percentage of moisture in the cob was greater than in grain, the samples were stored in bags for drying. It was planned to make a final weighing and moisture determination after the samples were thoroughly dry but circumstances prevented making the moisture test. The Indiana statisticians believe the method developed in that State to be a useful procedure in estimating corn yields, especially when used as a means of fixing a level for observed on a field trip in yield intervals by use of the crop meter.

Iowa Crop Reporting District 5: In 1938 the Division of Agricultural Statistics began intensive studies on corn ear measurements and weights. This project is centered at Ames and consists of intensive weather-yield studies on plots of the Experiment Station there and field observations and measurements over a route of approximately 500 miles in Crop Reporting District 5 (central Iowa). Ear counts and measurements were quite similar to those made on the Crop Reporting Board route. The work in District 5 provides an opportunity to try out on a small scale, methods of technique analysis, the more promising of which can subsequently be applied to the material gathered by the Crop Reporting Board. In order to learn more about the trend in size of ears from the blister stage on through to maturity, a random selection of ears on the plots at Ames in 1939 were measured for length and diameter at weekly intervals throughout their development. Similar measurements were made on the plots at Urbana, Illinois.

The work of the Research Office on corn ear measurements and weights has been carried on largely by F. E. Davis and J. R. Goodman of the Agricultural Marketing Service. The project was started in 1938 and consists of (1) intensive weather-yield studies at Ames, and (2) field observations and measurements in Crop Reporting District 5 (central Iowa). Early in 1938, two routes of approximately 250 miles each were laid out in District 5 in cooperation with L. M. Carl, Agricultural Statistician at Des Moines.

Complete observations included ear measurements and number of ears on an adjoining 10 hills at two locations in each field. This was done in order to make an analysis similar to that made on the 1938 material.

Conversion factors concise enough to warrant an estimate of yield for District 5 for comparison with the official yield for the District have not been worked out. Analyses have been made on the material from District 5 to bring out the variation from field to field in ear numbers per area and in ear size. Estimates of sampling error within the fields have been made insofar as the data will permit.

The analyses show that the variation from field to field in number of ears per unit area and in size of ears was large in comparison with variation within the field. This indicated the necessity of sampling as many fields as possible. For 1938 the variance in number of ears between two samples within a field was no larger than the variance of this factor between hills within the samples. This could be interpreted to mean that counting ears in a second spot in the field did not give any more information than counting ears on hills near the first sample. In 1939, however, the variance between the two samples within a field was larger than the between hill variance, which fact points to a conclusion opposite to that drawn from the 1938 data.

By taking a ratio between the coefficients of variability of ear numbers and of ear sizes weighted in proportion to the time required for each operation, it was found, from the 1938 data, that approximately 40 ears should be counted for every 10 measured for most efficient allocations of time in the field.

In order to learn more about the trend in size of ears from the blister stage on through to maturity, the field assistants on the plots were asked in 1939 to measure weekly the length and diameter of a random selection of ears throughout their development. The results show that both ear length and ear diameter increase until approximately the middle of August and then decrease until harvest. These seasonal trends must be considered in any estimating or forecasting equation.

As the result of his intensive work at Ames, his corn route studies in Crop Reporting District 5 of Iowa, and the experience gained during the previous 3 years on the Corn Belt route of the Crop Reporting Board, F. E. Davis made the following suggestions for Board corn trips following the 1939 survey:

Provision should be made to study sampling error in fields in various parts of the Corn Belt. This might be done either by taking several samples in every fourth field or by dividing the Corn Belt into similar sections and designating a given number of fields to be sampled thoroughly in each. The approximate location of the fields should be chosen in advance. In no case should the character of the field enter into the choice. The samples from the field should be strictly at random within the portion of the field the samples are allowed to fall. When this increased sampling is to be done in a field, the farmer should be contacted and permission asked for taking samples for moisture and for studying conversion factors.

Two ears should be taken from each field for studying conversion of measurements to weight.

Preliminary results from 2 years' work in District 5 (central Iowa) show that the sampling error in number of ears per unit area may be large enough to warrant counting ears in more than one sample. Possibly the two men in the crew should enter the field and record ear measurements on one sample following which they should deploy into the field and count the ears of different samples.

It is suggested that the time at which the Crop Reporting Board makes the counts and measurements be as constant as possible from year to year.

Based on an analysis of the 1940 data, J. R. Goodman made the following recommendations for the "Washington Route" corn survey:

Include in the sampling program the collection of ears for drying out in order to compute moisture precentage. The moisture percentage of ears enters into the regression equation.

Limit the taking of samples to one location in each field (except that ear counts should be taken at three locations per field as was done in 1940).

Using the technique developed in pre-harvest wheat surveys, modify the route traveled, where necessary, in such a way as to facilitate making district yield estimates in the territory covered.

There are no fundamental reasons why the yield of corn in a field cannot be estimated to any degree of accuracy just previous to harvest. In principle, estimation of district, State, or regional yields is no more difficult. It is only necessary to take adequate samples from a sufficient number of fields just before harvest. There are certain practical difficulties, however, that stand in the way of estimating the average yield per acre at harvest. In determining the magnitude of these difficulties it is important to know the number of fields and the amount of sampling in a field that will be necessary to give estimates of the required accuracy. For this purpose it is necessary to determine (1) the variation from sample to sample within a single field, (2) the variation in yield from field to field in a crop reporting district.

It is an accepted principle that, to obtain a valid estimate of sampling error, two or more sampling units must be selected at random from the whole aggregate of sampling units that can be taken from the field. For a valid estimate of the standard deviation between fields, the fields must be chosen at random from those in the district.

The above need for a random selection must be faced squarely. If in practical sampling schemes it is necessary to some extent to sacrifice randomization, one must be cautious of the inference drawn from the estimates of sampling error. Such inferences cannot be treated with the same certainty of inferences as when strict randomization is observed. In any given case the lack of randomization may make little difference, but one cannot always be sure. The extent to which information is already available may be considered by the practitioner.

Complete objectivity in the selection of the actual material for the sample must be stressed even after the random selections of locations are made in the fields. In order that the material in the samples may be properly representative of the whole, the selection must be uninfluenced by the qualities of the objects sampled and free from any element of choice on the part of the observer.

FORECASTING FROM CROP-WEATHER RELATIONSHIP

When the Bankhead-Jones Act was passed by Congress, funds became available for basic research in agriculture. A study of the relation of weather to crop yields was begun in 1936 with a comprehensive and intensive survey of the literature and available data on crop yields and weather records at several agricultural experiment stations. It soon became apparent, however, that the available data were inadequate and that additional research was needed. Accordingly a research project was inaugurated to investigate the possibilities of long-range weather and crop forecasting, including a study of the relation of weather to crop yields. This is a cooperative project involving the Agricultural Marketing Service and the Bureaus of Plant Industry, Entomology and Plant Quarantine, Weather, Soil Conservation Service, Massachusetts Institute of Technology; and State experiment stations of Kansas, Nebraska, Iowa, Ohio, North Dakota, South Carolina, Georgia, Mississippi, Arkansas, Oklahoma, and possibly others.

The objectives of this study can be summarized as follows: (1) to improve regular crop forecasts by discovering and applying relationships between yields and weather factors; (2) to include in the objective basis for forecasting, the relationship of structural counts and measurements and phenological records of yields, either separately or with weather factors; (3) to develop a basis for making forecasts of the quality of the crop based upon plant and weather observations that are likely to be useful in forecasting crop yields.

The research was conducted in corn, wheat, and cotton and can be divided into three parts. The first part consists of the relationship between yield per acre and the observations on the growing plant that can be taken prior to harvest and will therefore provide a basis for forecasting yield. The second part consists of a study of the relationship between yield per acre and observations of the plants' environment that occur prior to harvest. The third part consists of a study of the relationship between yield and a combination of observations on the growing plants and observations of the plants' environment prior to harvest.

The supervisory leaders include W. F. Callander and P. L. Koenig of the Agricultural Marketing Service and M. A. McCall, H. W. Barre, and S. C. Salmon of the Bureau of Plant Industry. Representatives from the Agricultural Marketing Service are A. J. King at Ames, Iowa, directing the work on corn and wheat and A. L. Finkner at Raleigh, North Carolina, directing the work on cotton.

CORN

The crop-weather research on corn is conducted at Ames, Iowa and is now in its fourth year. The experimental work is designed with the following objectives: (1) The use of experimental plots as a source of data for (a) objective study of relationships between plant measurements and final yields, (b) objective appraisal of environmental factors and their relationships with yield, either alone or in conjunction with the measurements mentioned in (a); (2) laboratory study of pollen, its viability under varying conditions, together with experimentation on methods of germinating pollen; (3) route sampling in Crop Reporting District 5 of Iowa in order to test out objective methods which appear promising in estimating yields; (4) analysis of experiment station data from station records.

The experimental plots are utilized for the intensive physiological investigation. Measurements on the growing crops, made periodically, include leaf height, leaf area, ligule height, stalk diameter, ear length and ear diameter. Dry matter determinations are made weekly and samples saved for chemical analysis. Such phenological dates as planting, emergence, tasseling and silking are recorded. The plant's environment is expressed in terms of a daily record of air and soil temperatures, precipitation, relative humidity, and evaporation. Studies of soil moisture include tensiometer readings and laboratory analysis of tube samples. Final plot yields are determined on the basis of portion of plots remaining; i.e. not harvested for the weekly dry matter determinations during the season. The Ames data are supplemented by the use of plots at six other corn belt stations, where the procedure is less intensive in that dry matter determination and laboratory analysis are omitted. The six stations are: Lincoln, Nebraska; Clarinda, Iowa; Manhattan, Kansas; Urbana, Illinois; Madison, Wisconsin; and Wooster, Ohio.

Each variety is replicated six times at Ames, and generally four times at the other stations. The decisive trend of the corn producers in the Corn Belt toward the planting of hybrid seed led in 1940 to selection of four new promising single crosses along with the two former double crosses grown the two preceding years. The six varieties or crosses were planted at each of the following stations

located across the Corn Belt; Lincoln, Ames, Urbana, and Wooster. At the remaining three stations varieties best suited to the localities were grown.

Results of the analysis to data have served to emphasize the long-range aspect of the project. However, some significant conclusions are available. The small amount of difference in yields from year to year to date for varieties grown at Ames has restricted the study of yield relationships, and it is obvious that this investigation will need to cover poor corn seasons as well as good ones.

The use of the same varieties at four of the stations in 1940, with the resulting wide difference in the yields, has made possible the study of between station correlations. The calculations are now under way and both ligule height and ear measurements appear promising indicators of yield as early as mid-August.

Correlating successive weekly ear measurements (length x diameter) with the percentage of moisture in the ears as shown by dry matter determinations from the same plots resulted in an r of .995 which indicates the close relationship existing between the shrinkage of the ear and its moisture content. The conclusion is that the percentage of moisture in the ears is an additional factor which must be taken into account in correlating ear size with yield.

The conclusion in general is that the amount of sampling done is sufficient for our purposes. The standard error of the final yields may be reduced slightly by leaving a few more sampling units for harvest, but this would mean a corresponding reduction in the number of weekly dry matter determinations. Investigations are now in progress concerning the correlations of plant measurements with one another. Ligule height and dry matter appear to be significantly correlated up to a certain stage in the plant's development. Information of this type will be valuable in planning future plot work.

Following are the conclusions based on the artificial germination studies to date:

Drying breifly increases percentage germination of pollen from a newly dehisced anther by reducing bursting of the damp grains. Much pollen, however, fails to fall after the anther ruptures until the tassel is jarred. Such pollen is able to germinate at once.

High temperatures limit the duration if viability, certainly by increasing the rate of water loss from the pollen, andprobably by exhausting food reserves through increased respiration. A temperature of 105 degrees F. applied to corn pollen for 30 minutes renders most grains incapable of germination on nutrient media.

Storage of maize pollen with high retention of germinating ability has been accomplished for periods varying from 5 to 10 days at temperatures from 33 to 50 degrees F. under conditions where relative humidity was never allowed to reach 100 percent. These data are in sharp contrast with the literature on storage of corn pollen, for 48 hours is the greatest duration of germinability previously reported. Two hours to 1 day have been more frequently recorded as the limit.

Relative humidity becomes critical in periods as short as 30 minutes when pollen is subjected to 100 degrees F. Such pollen germinates not at all if the heat treatment is accompanied by 20 percent relative humidity; little tube production follows if the humidity is raised to 50 percent; but 100 degrees seem not to be injurious when the relative humidity is 80 percent.

At a temperature of 75 degrees, pollen, which is viable for only 2 hours in the open air of the laboratory where relative humidity is about 30 percent, can be preserved from 12 to 30 hours in a chamber at 98 percent humidity.

Statistical analysis of weather-yield relationships based on experiment station data was continued during 1940. In a manuscript now in press, (Technical Bulletin 806, of the Department), Davis and Harrell have reported on the investigation of the relation of weather and its distribution to corn yields in Ohio, Indiana, Illinois, Iowa, Nebraska, Kansas, Missouri, and Kentucky. They found among other conclusions that: (1) On the average, maximum temperatures are too high for corn under the moisture conditions encountered at the various locations. The effect of maximum temperatures above average is more pronounced at locations having the highest average seasonal temperature. Maximum temperatures above average in both July and August are detrimental to corn from one extreme of the Corn Belt to the other, while with the exception of Urbana, Illinois above average temperatures in May and early June are beneficial to corn. (2) Maximum temperature seems to be the governing weather factor in its effect upon corn yields. At least part of the beneficial effect of additional rainfall is due to the associated effects of the accompanying lower temperature. (3) A comparison of the effect of the amount and distribution of rainfall on the same variety of corn grown under divergent cultural conditions at Wooster, Ohio, indicates that effect differs markedly between high and low yielding series. (4) The rainfall effect curves show almost unanimously that above average rainfall at germination and emergence is not beneficial and in several places appears detrimental. (5) In studying weather-yield relationships for a single crop at several locations the expressions of relationships obtained by the method of analysis employed in this study appear superior to ordinary regression expressions for making biological interpretations.

COTTON

A pilot experiment on cotton-weather research was begun at Florence, S.C., under the supervision of J.J. Morgan in 1938. The two-fold purpose of the experiment was (1) to determine the most useful experimental design, and (2) to observe such factors as plant growth, blossoming, and fruiting which would give the maximum information with the least amount of field work. The results obtained were highly satisfactory and valid conclusions were drawn to the effect that confounded factorial design involving four varieties, two dates of planting, two levels of fertility, and two complete replications resulted in a maximum amount of information with the least cost. The varieties used were Oklahoma Triumph 29-44, Stoneville 5, Farm Relief, and Dixie Triumph. These varieties were chosen to represent extremes in types of growth and a range in dates of maturity. The two dates of planting, a normal and optimum for producing maximum yield and a planting approximately 3 weeks after the normal planting, were included to study the response of plants at two stages of growth to a given weather condition. The two levels of fertilization, optimum or "high" for producing maximum yield and one-third of the high rate usually referred to as "low" were incorporated into the design to study the effect of fertility levels on plant growth and other characteristics.

A four row plot, 103 feet 8½ inches long, and a drill row of 42 inches, giving an area of 1/30 of an acre was decided to be a satisfactory plot size as well as conforming to agronomic and statistical recommendations. The sampling units on which plant measurements were taken consisted of four 5-foot units located at random on rows 2 and 3. The kind of plant observations best suited to reflect the growth and development of the plant were assumed to be daily

emergence, weekly height measurements, weekly square counts, daily bloom counts, daily shedding by date of bloom, size of green bolls, weekly boll counts of bolls 15/16 of an inch or greater in diameter, daily opening by date of blooms, phenological date of squaring, blooming, and opening, percentage of three, four and five lock bolls, yield of seed cotton in samples and yield of seed cotton in plots. The samples were then ginned to obtain yield of lint cotton and lint and seed indices. Dry weight of plants were obtained in 1938, but this measurement showed an almost perfect correlation with height. Height, of course, was much simpler to measure with a less expenditure of time, so dry weights were discontinued.

Weather records consisted of rainfall both as to time and amount, daily evaporation from white replicated atmometers, evaporation daily from an open water pan, wind velocity and direction, relative humidity at 8:00, 1:00, and 5:00 o'clock each day, maximum and minimum temperatures, a measure of overcast three times daily, and a measure of soil moisture by use of soil tensiometers.

Five specially designed field experiments carried on for a period of 5 years could be expected to give much more useful information than one project carried on for a period of 25 years. In addition, the results from the pilot experiment in 1938 were highly satisfactory. On the basis of this reasoning, it was decided to expand the project to four other stations in 1939 in addition to the one at Florence, S.C. The stations chosen for this work were Georgia Experiment Station, Experiment, Ga.; Delta Experiment Station, Stoneville, Miss.; Cotton Branch Experiment Station, Marianna, Ark.; and the U. S. Dry Land Field Station, Lawton, Okla. The experimental design used in 1939, 1940, and 1941 at the five stations was identical with the design decided upon by the pilot experiment at Florence with a few minor exceptions. These changes included substituting Stoneville 2-B for Stoneville 5, and Shafter Acala for Farm Relief. At Lawton, Okla., two spacings (one plant every 10 inches and one plant every 20 inches) were used instead of fertility levels since fertilizer is not a problem in the dry land area. The main objectives of this experiment are: (1) to study the interrelationship of plant characteristics, (2) to study the relationship between plant observations and yield per acre, and (3) to study the effect of weather on plant growth and yield.

Analysis of variance was run on the 1939 data, a separate analysis being made for each variable. All main effects were significant as would be expected from the design of the experiment. The main objective in calculating analysis of variance was to determine the nagnitude and probable origin of the error term, a knowledge of which is advantageous when considering regression analysis. On the basis of the 1939 data, the percentage of bloom set seemed to follow closely the temperature and moisture conditions during blooming for both normal and late plantings. As a rule the growth rate for late cotton exceeded the rate for normal cotton at the same locations because factors affecting growth are usually more favorable as the season progresses.

In studying the correlations of the various plant characters with yield of cotton, it seems that the combination of boll size and number of bolls would give a more reliable prediction of yield than any two other variables. For this reason, number of bolls and boll size were correlated with yield of lint cotton per 20 feet of row, yield of seed cotton per 20 feet of row, and yield of seed cotton in pounds per acre.

The simple correlations between number of bolls and yield are highly significant. When varieties are excluded, the correlation are, as a rule, consistently higher than the corresponding correlation with varieties included. This

can easily be explained logically since within a variety, the greater the number of bolls the greater the yield. When varieties are included, the effect of the extreme types of Dixie Triumph and Acala become apparent and decreases the correlation.

The multiple correlations involving number and size of bolls with yield are all highly significant. The impressive fact seems to be that all multiple correlations within varieties and with varietal effect included are almost identical for corresponding stations and years.

Regressions were calculated for analysis with varietal effect included in which the "size of bolls" variable was held constant, i.e. in the predictive equation, the mean of the values for size of bolls was used as this variable. The regressions were plotted in order to give a visual interpretation of the slope and spread of the regression lines and are shown in figures 1 and 2.

An approach is being made to the physiological angle by a modified, somewhat more intensive design being carried on at Raleigh, N.C., under the supervision of J. A. Rigney of the Department of Experimental Statistics, North Carolina State College, and J. J. Morgan of the Agricultural Statistics Division, Agricultural Marketing Service, and under the immediate direction of D. D. Mason, Cooperative Agent of the two agencies.

One of the main objectives has been to develop accurate measurements of total soil moisture available to plant roots under varying conditions. A comparison of the following methods of soil moisture measurements was intended: (1) Shaw-Baver heat conductivity method, (2) Richard soil tensiometer method, (3) soil sample method by dry weights, (4) Bouyoucos method. However, elements for the Shaw-Baver and Bouyoucos method were not available this year and soil moisture was necessarily measured by the two remaining methods.

A soil analysis of the plots was made at intervals to determine leaching and loss of nutrient to the plant. Observations in 1941 seem to indicate that nutrients are lost to plants more rapidly under acid conditions.

Another objective of the project is to develop an adequate measure of water stress in the plant. Water stress in a plant is directly related to growth and hence to yield. Accuracy of prediction of crop-yields is therefore contingent upon a thorough understanding of some of the fundamental factors involved in determining water stress in plants. The phenological stage at which such deficits occur and their duration and severity have an important bearing on their ultimate effect. A rough method of measuring degree, time of occurrence, and period of wilting was initiated this year. It is hoped to refine this method and perhaps to develop new methods for the next crop season.

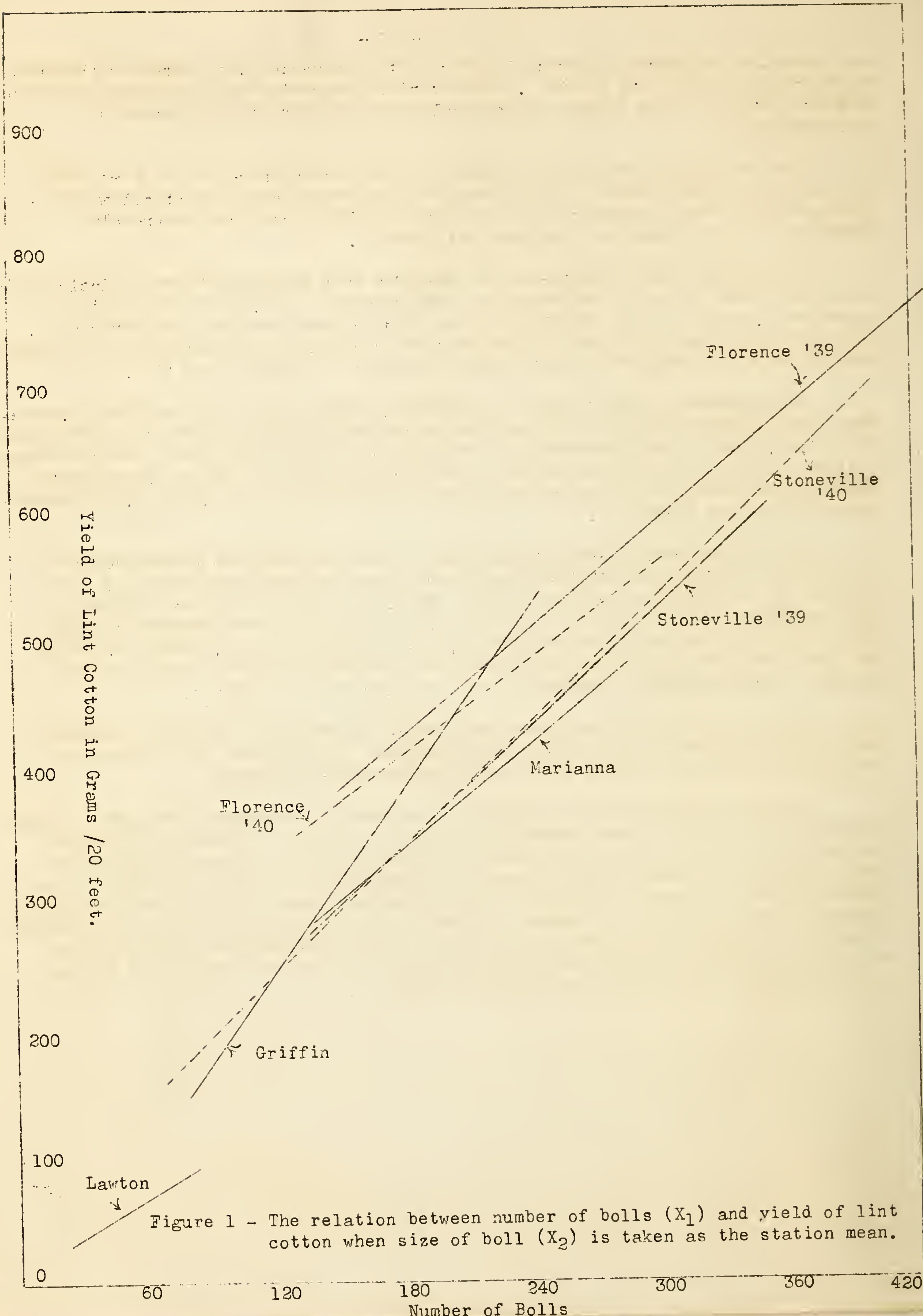

Figure 1 - The relation between number of bolls (X_1) and yield of lint cotton when size of boll (X_2) is taken as the station mean.

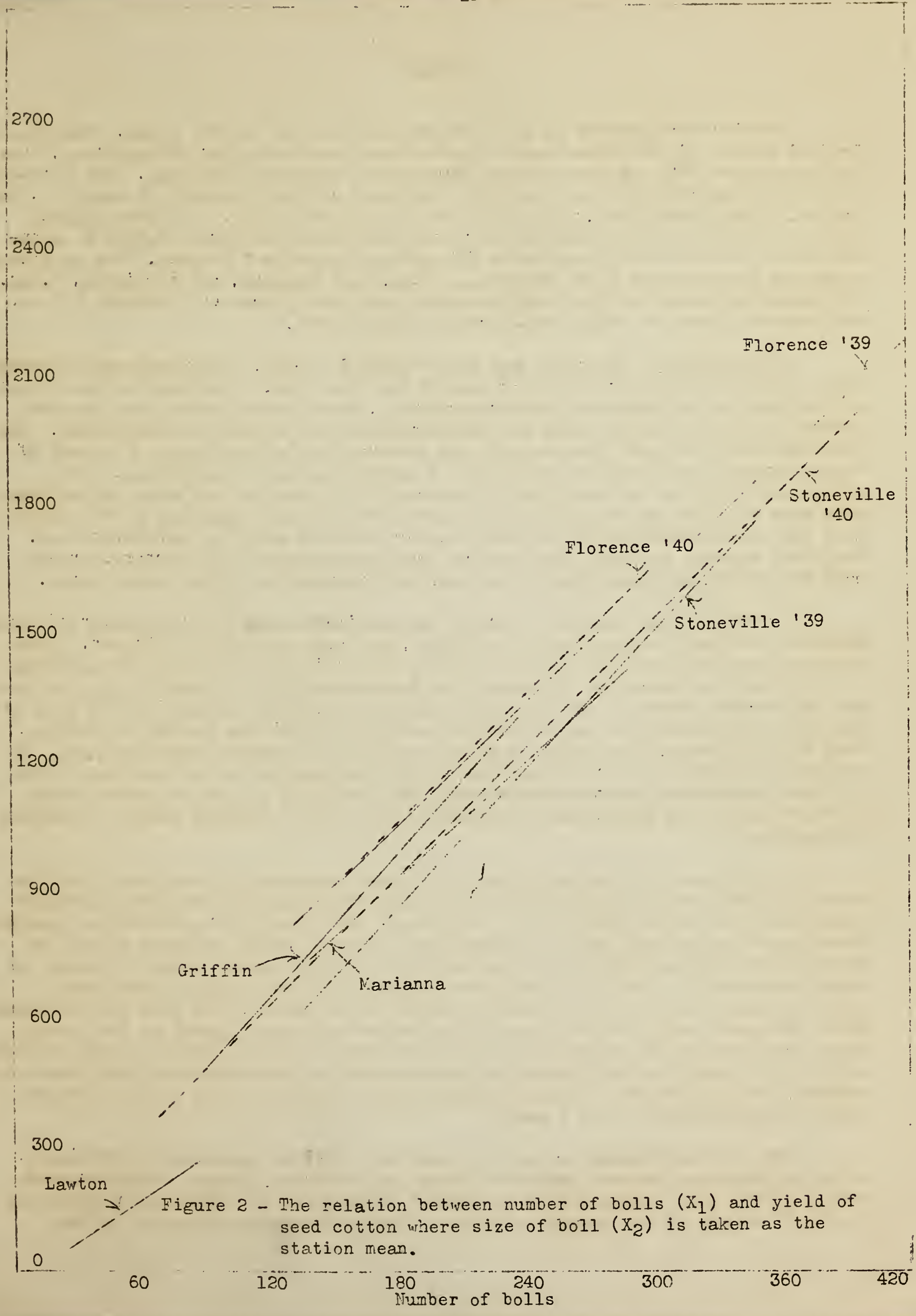

Figure 2 - The relation between number of bolls (X_1) and yield of seed cotton where size of boll (X_2) is taken as the station mean.

WHEAT

Studies were carried on for both winter wheat and spring wheat. The physiological phases of the winter wheat studies have been conducted at Manhattan, Kans. in cooperation with the Kansas State College and Experiment Station. The agronomic phase is being carried on at the five experiment stations located at Amarillo, Tex.; Lawton, Okla.; Hays, Kans.; Lincoln, Nebr.; and Akron, Ohio. The physiological phase of the spring wheat studies have been carried on at Fargo, N.Dak. in cooperation with the North Dakota State College and Experiment Station. The agronomic phase has been carried on at Crookston, Minn., and Langdon, and Dickinson, N.Dak. The extensive phases of the wheat research have been discussed elsewhere in this publication under the title "Pre-Harvest Wheat Survey."

Winter Wheat: Agronomic and Physiological phases. Four varieties of wheat were seeded in triplicate plots at each of the stations. The plantings were made on two dates at all stations except Manhattan, where these four varieties were seeded only at the normal date and two varieties were seeded at seven dates. The investigations included measurements and observations of the plant, a record of tillage methods and field conditions, and meteorological observations. The meteorological observations, the tillage and field records, and some of the plant data were obtained at the respective experiment stations. Samples of the plants from the plots were shipped to Manhattan for detailed study in the laboratory. The plant studies included phenological data, information on the character and rate of growth, and quantitative and qualitative measures of the mature crop.

At each of the vegetative stages the available data include number of plants, number of tillers, average weight of plant, and average weight of tiller. These measures were obtained also in the fruiting stage in the experiment at Manhattan and the number of heads at this stage was determined at all the stations. As the crop approached maturity the yield of grain was determined as well as the size of the head with respect to length, weight, weight of grain and number of kernels. Also size of grain, test weight of grain, and protein content were obtained. In the further analysis of the data, inquiry will be made as to the features of the physical environment that are associated with desirable as well as undesirable characteristics and conditions of growth of the crop at various stages throughout the season.

In the study of the relationship of plant character it was found that the growth of wheat as early as the first of December was associated with subsequent development and yield of the crop. In general the crops that attained the greatest development in the fall made correspondingly greater growth in early spring and subsequently produced the most heads per area and the largest yield of grain. A closer association with yield was observed for plant measurements made near maturity than earlier in the season as should be expected. The late planted wheat, after emergence was attained, developed faster than that planted at the normal date, resulting in the former overtaking the latter with respect to number of heads and yield at Amarillo and Lincoln and approaching the development of the wheat at Lawton. The difference in time of planting was 2 weeks at each of the stations except Lincoln where it was 1 week.

The relation between weight of plant and yield of grain was curvilinear, while the relation between number of heads and yield was linear. Further examination of the data revealed that in general these types of relationship prevailed for each variety at the several stations. The relationship indicated by the

replicate plots of a variety at each station conformed in general to the overall curve at the particular level. The relationship, however, did not apply among the varieties planted at the same time at a station because of genetic differences which resulted in different means for the characters measured.

The statistical constants for these various relationships have not yet been determined. The completion of a critical statistical study of the data furthermore will aid in pointing out the particular plant measure at each stage of development that most accurately represents the biological condition of the crop and the potential capacity for future development and yield.

Spring Wheat: Agronomic and physiological phases; The work at Fargo was performed with Thatcher, Ceres, Premier, and Mindum varieties sown on two different dates about 2 weeks apart, normal and late. The experiment was arranged in a randomized block with 4 replications. The measurements and an analysis included date of planting, rate of seeding, date of emergence, date of first tillering, date of first heading, date of 50 percent heading, date of complete heading, date of ripening, date of harvest, periodic dry weight determinations on plants and heads, measurements of plant height, thickness of stand, number of tillers, leaf area, number of heads, length of heads, soil moisture and nitrogen content, phosphorus content of plant, insect and disease damage, weed infestation, lodging, weight of threshed grain, protein content of grain, moisture content of grain, number of kernels per spikelet, weight and moisture content of straw, and various meteorological measurements such as air temperature, humidity, precipitation, rate of evaporation, and wind velocity and direction. Similar but less elaborate experiments involving the same wheats were carried out at Crookston, Minn., and Langdon and Dickinson, N.Dak. There were three replications only at sub-stations. Analysis of the data is still in progress. A summary of the more obvious results, however, is presented below.

There was little difference in length of heads between a given variety for the two dates of planting. There were some slight differences within a variety at the several stations. Whether these differences are significant remain to be seen when the yields and other characteristics are compared. At all stations the higher yields were obtained from the early plantings with marked differences within a variety grown at the various locations.

In general the early planting produced the heaviest kernels although the variety Thatcher was practically the same for both dates of planting at all stations except Fargo, and at Langdon Mindum was the same for both dates.

Soil moisture measurements were made at the various stations. However, since all these soils are different chemically and physically no direct comparison can be made between stations until further calculation, based on soil characteristics, are completed.

For the Fargo studies it was planned to take samples at 2-day intervals beginning at least 14 days before normal harvest. This schedule was not fully realized owing to a hot spell about 2 weeks before normal harvest which hurried the grain along. The chemical analysis and the milling and baking studies based upon the Fargo studies showed that flour yields were quite variable with the early pre-harvest samples frequently somewhat lower than final harvest samples. Loaf volumes were generally good but significantly variable from station to station indicating that there is a definite difference in the baking strength of the samples which probably relates to environmental factors. Another interesting feature was the excellent baking quality of some of the first pre-harvest samples which while largely composed of green kernels still baked well.

Of the plant counts and measurements made on the samples of wheat obtained during the pre-harvest wheat survey, it was found that the number of heads per unit area, which is one of the first plant observations that can be readily taken, is highly correlated with yield and will therefore give a basis for forecasting the yield. The same relationship is found on data collected from the experimental plots.

It was found that an additional variable, height of plant, materially increased the accuracy of the forecasts. However, if the forecasts were made before the plants had completed their growth, it would be necessary to use height at some particular stage of growth, and in this case the height may then show a different relationship. In England it was found that height, when the plant reached a maximum rate of growth, was highly correlated with yield. It might therefore be found that if the height of plant were taken when the number of heads is obtained, a better forecast might be given. Height at that time would be approximately the time when the plant is reaching its maximum rate of growth. It is planned to study the relationship of yield and height at different stages of growth. This study will be based upon the experimental plot data.

NOTE ON COMING PUBLICATIONS

Theoretical Aspects of the Use of the Crop Meter - By W. A. Hendricks

This report is now being printed by the Works Project Administration in New York City and should be released before January 1, 1942.